Fast Ferry Program - Wake and Wash Study

Fast Ferry Program - Wake and Wash Study/Executive Summary

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Glossary

Nautical Mile:	1 nautical mile (1 nm) = 1852 m or 1 minute of latitude
Knot:	1 knot (kt) = 0.5144 m/s. A vessel travelling at 1 knot travels 1 nautical mile in one hour.
LOA	Length overall; the overall length of a ship
Bathymetry	The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.
Celerity	The speed of individual waves in a wave train.
Group Velocity	The velocity of the group of waves in a wave train. In deep water, it is equal to one-half the celerity of the individual waves within the wave train.
Cusp Line	The line defining the approximate perimeter of the wake wave disturbance behind the vessel. In deep water, the cusp line is at an angle of 19.5° with respect to the ship track.
Amplitude	The magnitude of the displacement of the water surface in a wave from a mean value. An ocean wave has an amplitude equal to the vertical distance from still-water level to wave crest.
Significant Wave Height	The average of the highest one-third waves in a group of waves.
Peak Period	The wave period corresponding to the most energetic waves in a group.
Red-to-Red	Refers to the practice of ships passing port-to-port.
Green-to-Green	Refers to the practice of ships passing starboard-to-starboard.
Wave Height	Two times the amplitude.
Waypoint(s)	Location, defined by latitude and longitude, generally corresponding to a location on a route where the vessel heading or speed changes.

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Executive Summary

Background

This report describes the investigation and assessment of the wake waves generated by the PacifiCat fast ferry and the development of an integrated approach to mitigating the wake effects. In July 1999, the British Columbia Ferry Corporation (BCFC) commissioned the first catamaran ferry, PacifiCat Explorer for service on Route 2 between Horseshoe Bay and Nanaimo. Initial operations of the PacifiCat Explorer resulted in complaints and expressions of concern to BCFC regarding the effect of the vessel wake. As an initial and precautionary response to these concerns, BCFC modified the course and speeds of the PacifiCat vessels, based on preliminary observations and fast ferry experience elsewhere. In September 1999, a study to characterise the PacifiCat wake and wash, and to develop operational strategies to mitigate the wake effects was awarded to Sandwell Engineering Inc.

Objectives

The objectives of the study described in this report are:

- to identify the key components of the wake generated by the PacifiCat class of vessels
- to define the propagation and decay characteristics of the wake components
- to determine the sensitivity of the wake characteristics to various vessel conditions
- to define the interaction of the wake components in shallow water with the shoreline and shoreline structures, and with marine habitat
- to define the relative magnitude of the wake components with respect to both the natural wave climate in the Strait of Georgia, and the wake generated by the C-Class vessels operating on the same route as the PacifiCat
- to assess the PacifiCat wake effects, and to develop appropriate mitigation measures
- to provide a sound knowledge-base to allow evaluation of wake effects and the development of operational strategies which meet the requirements of BCFC for the operation of the PacifiCat class of vessel.

Review of Ship Wake Theory

The well-established theories of ship wake wave behaviour were reviewed to determine their application to the PacifiCat class of vessels and the expected characteristics of the PacifiCat wake. This study has shown that classical theory is applicable to the PacifiCat vessels.

Wake Measurement Program

The PacifiCat wake wave characteristics were determined by means of a thorough test program, which involved aerial observations, surface observations and two wake measurement programs with vessels in the 75% and 0% loaded condition, respectively. Measurements of the wave height, period, propagation and decay characteristics of the diverging and transverse wave systems were obtained. The test program was designed to determine the sensitivity of these properties to the effects of varying speed, offset from track, vessel trim, vessel load, and to determine the wake characteristics during turns.

Based on the analysis of the measured data, and confirmed by further tests and observations during the shoreline site visits, the characteristics of the predominant components of the PacifiCat wake are shown in Figure 1 and summarised in Table 1 as a function of vessel speed.

Figure 1 PacifiCat wake system

Table 1 PacifiCat wake system characteristics

Wake component	Propagation angle (from vessel track)	Wave period (s) (V_s = vessel speed in knots)
Primary diverging	35°	0.27 V_s
Secondary diverging	70°	0.11 V_s
Transverse	0 °	0.33 V_s

The main results of the test program indicate that:

- the characteristic wave heights of the wake components vary considerably with vessel speed and the distance which the waves have travelled from the vessel track. Details of wake wave heights are provided in Section 3 of the main report.
- the PacifiCat wake system consists of three diverging and one transverse wave group. The primary diverging wave height decays in proportion to $1/\sqrt[3]{x}$, where x is the wave propagation distance. The secondary diverging and transverse wave heights decay more rapidly in proportion to $1/\sqrt{x}$. The tertiary wave component was not investigated in detail in any of the wake measurement programs, due to its small magnitude and similarity to mild background wind-driven waves.
- as the wave height decays with increasing distance from the vessel track, the total number of waves in the wake system increases, resulting in an increased duration of wake effects.
- increasing vessel load does not influence the heights of the PacifiCat diverging wave components but does increase the transverse wave height.
- trim tabs are relatively effective in decreasing the primary diverging wave height at speeds below 30 knots. They are moderately successful in reducing the height of the primary diverging wave above 30 knots, and the secondary diverging wave at all vessel speeds.
- in the area on the outside of a turn, the wake wave height is reduced in comparison to the wake produced from a straight-line course at the same speed.

Criteria for Defining Wake Effect

A literature review of the fast ferry wake and wash studies performed to date has shown that wake effects are site-specific and an industry standard methodology for assessing fast ferry wake wash has not been established. Since fast ferry technology is relatively new, little published work is available and most studies have dealt with fast ferries operating in shallow water. As most of the PacifiCat route is in deep water, many of the unique characteristics attributable to wake issues elsewhere do not occur and therefore, the criteria used in most past studies are not directly applicable to the present PacifiCat study. Previous studies focused on specific wake characteristics, which often reflected specific concerns of the main users affected by the wake. These did not provide a comprehensive means for assessing the impact on all users in all scenarios. In this study, a methodology which addresses all the characteristics of the PacifiCat wake was adopted.

Many previous studies selected the wake of an earlier generation vessel as a standard by which to assess the wake of a new vessel. This standard ignores issues about the acceptability of the wake from the earlier vessel. To account for this limitation, the natural wave climate in the Strait of Georgia has been chosen as the primary standard for assessment of the PacifiCat wake. Through this comparison, it can be determined whether the PacifiCat wake is different than the wave effects that occur naturally in the Strait of Georgia. For this study, three natural wave events

have been selected for comparison with the PacifiCat wake. These storm events are defined in Table 2.

Table 2
Natural wind-generated storm events

Storm Event	Significant Wave Height (m)	Associated Peak Wave Period (s)
WEST SIDE OF THE STRAIT OF GEORGIA		
Minimum weekly summer event[1]	0.8	3.6
Minimum annual winter storm[2]	2.7	6.6
Severe winter storm[3]	3.4	7.3
EAST SIDE OF THE STRAIT OF GEORGIA		
Minimum weekly summer event[1]	0.8	3.6
Minimum annual winter storm[2]	2.2	5.8
Severe winter storm[3]	2.9	6.7

[1] Minimum weekly summer event: This event is the minimum storm wave condition expected on average once per week (nine times per July-August summer season). The conditions in this category also include a maximum significant wave height of 2.2 metres, and associated peak periods of 5.9 seconds, and an average significant wave height of 1.1 metres with a peak period of 4.3 seconds.

[2] Minimum annual winter storm: This event is the minimum storm wave condition expected on average once annually. The conditions in this category also include maximum significant wave heights of 3.4 metres and associated peak period of 7.3 seconds, and an average significant wave height of 2.8 metres and peak period of 6.7 seconds.

[3] Severe winter storm: This storm is the maximum wave condition that occurred in the 23 years of record.

Assessment of Wake Effect

The results from the wake measurement programs defined the effect of various vessel conditions on the deepwater wake wave height. It is necessary to assess the effect of shallow water on the deepwater wake waves to define the wake effect experienced on the adjacent shorelines.

After classifying the shorelines adjacent to Route 2 in terms of their exposure to the wake, and by calculating the magnitude of various wave-shoreline interactions including:

- wave shoaling
- wave breaking

- wave runup on beaches and rocky shorelines
- the potential to mobilize seabed sediments,

the main conclusions of the wake effect assessment are:

- The relationship between the height of waves, or the energy, in a PacifiCat wake and a C-Class vessel wake is complex and not consistent throughout the entire area effected by PacifiCat wake. This lack of any constant trend or relationship illustrates the inadequacy of assessing wake based on the wake of a previous generation vessel.
- Along large portions of the shorelines adjacent to Route 2, the energy contained in the PacifiCat wake waves, at a service speed of 34 knots, is greater than that experienced during typical summer storm events, but substantially less than that experienced during winter storms.
- As the shoreline becomes more distant, i.e., more than 3.5 nautical miles, both the height and energy of the PacifiCat wake waves are greater than those of a C-Class vessel when both are travelling at their service speeds of 34 knots and 20 knots, respectively, but similar, or less than, the conditions during typical summer storm events.
- In a few special cases, notably when a PacifiCat vessel is close to an area in question (less than 0.3 nm) and operating at less than 25 knots, the secondary diverging wake waves are both steeper and higher than wind waves generated during light to moderate wind conditions (defined by Environment Canada as 0 to 11 knots and 12 to 19 knots respectively). Unlike the other waves in the PacifiCat wake, these are close to the maximum theoretical steepness for waves. Many vessels can generate waves of this steepness and they exist naturally in tidal rip conditions. These steep waves merit special attention by mariners.
- Consideration of the effects of shallow water (typically less than 50 m depth and primarily close to shore in 5 m or less) on wave shoaling, breaking and wave runup indicates the following:

  a) along large portions of the shoreline adjacent to Route 2, the magnitude of the PacifiCat wake effects, i.e., breaking or runup, are generally greater than those from C-Class vessels or during summer storm event conditions, however, again, the relationships are complex and site specific.

  b) as wave breaking or wave runup are more characteristic of the response from individual waves, there will be situations when the PacifiCat wake effects will be larger than expected for the prevailing conditions.

- Consideration of the interaction of vessel and storm waves on typical seabed sediment types indicates that under certain conditions, PacifiCat wake has the potential to move some sediments which other vessel wakes do not. The interaction of all waves with shoreline sediments, both wake waves and storm waves, however, is highly complex and dependent on the local wave parameters, stage of tide, sediment characteristics and duration of exposure. In particular, the results of this study suggest that PacifiCat wake may not be capable of

moving sediments at locations where changes have been attributed to the first eight months of PacifiCat operations.

The results of the wave measurement programs undertaken in this study demonstrated that it is possible to mitigate some, if not most, of the effects described above. The wake wave measurements showed that:

- reducing the PacifiCat speed to between 20 and 25 knots results in breaking wave heights and runup at the shoreline which are similar to that of a C-Class vessel.
- turning the PacifiCat at 34 knots also results in breaking wave heights and runup which are similar to a C-Class vessel.
- these manoeuvres also result in wake effects at the shoreline that are generally less than those which occur during summer storms.

These results, together with other strategies, which account for the interaction of the PacifiCat wake with the shallow water bottom contours in the Strait of Georgia, have been used to develop alternative courses and speed profiles which successfully reduce the magnitude of the wave effects near and on the adjacent shorelines.

The results of the wave measurement programs have also made it possible to define operating strategies for the PacifiCat to minimize its wake effects on other vessels operating in close proximity.

Recommendations

This study has quantified and analysed the characteristics of the wake and wash generated by the PacifiCat class of vessels. The following recommendations are made for BCFC PacifiCat wake management practices:

- adopt new proposed routes W1 and E1, shown in Section 7 of the main report which mitigate wake effects on many adjacent shorelines while decreasing the total crossing time
- inform the PacifiCat crew of the wake propagation and decay characteristics and implement the wake management practices described in Section 6.2 which, define course changes to mitigate the wake effect on other vessels and adjacent shorelines, while minimizing the time spent travelling at reduced speeds
- develop a long-term, site-specific monitoring program to assess the physical/biological effects on selected adjacent shorelines to determine if future exposure to fast ferry wake exceeds the effects from other natural and man-made causes
- increase public awareness of the PacifiCat wake characteristics as they are noticeably different than those reported for fast ferry operations elsewhere in the world.